MAGNETOSTRICTIVE MATERTIALS RESEARCH AND DEVELOPMENT EXPERTISE STATEMENT OF WORK

1. TITLE

1.1 Scientific and technical support for NSWCCD, West Bethesda, Advanced Materials Branch (642).

2. OBJECTIVE/BACKGROUND

2.1 Provide physics and material science expertise to support the development of magnetostrictive materials (Fe-based magnetostrictive alloys, Terfenol-D) from basic research and material development through applications, taking into account the various and unique Navy requirements for the entire breadth of Navy needs from underwater transducers and sensors to shipboard vibration control and energy harvesting. Transducers and actuators ranging in size from nanoscale through large, high power projectors will be addressed. Performance over a wide range of temperature and shock loads as required by Naval systems and well beyond those experienced in the commercial sector, must be addressed and analyzed to assure both near and far-term performance. Specific tasking will be defined in writing, including description of effort, schedule, and deliverables, based on this base SOW.

3. SCOPE OF WORK

The contractor must be a PhD physicist with demonstrated extensive knowledge of and experience in the magnetic and magnetoelastic properties, e.g. magnetostriction, permeability, piezomagnetic constant, elastic moduli, and magnetic anisotropy of magnetostrictive materials. Specific and significant experience (more than 25 years) must be demonstrated in the 6.1 development of Navy and DoD-specific magnetostrictive materials such as Terfenol-D, Galfenol and high magnetoelastic coupling coefficient sensor materials and must have demonstrated the ability to formulate theoretical models for magnetostrictive materials. Experience aggregating more than 25 years is required with the following specific alloy systems: magnetostrictive RFe_2 and Fe-Ga alloy systems, where R is one or more rare earths for the temperature range of -60°C to 80°C; alloy design, e.g. proper choice of the rare earth components for the RFe_2 alloys and proper choice of Ga and X (Mn, V, Al, Co, etc.) for the Fe-Ga-X alloys to achieve desired transduction performance; high magnetoelastic coupling coefficient sensor materials. Also required is extensive knowledge of the use of these materials in Navy devices, e.g. vibration dampers, low frequency and piezomagnetic/piezoelectric hybrid transducers, and magnetic field sensors. The contractor shall provide technical services to 642 for typical tasks that include:

3.1 Sonar Transducer Materials Development

3.1.1 High-Strength Alloys with Moderate Magnetostriction Development - Current alloys with giant magnetostriction are quite brittle and expensive A need exists to develop less expensive, stronger alloys with magnetostrictions ~ 200 ppm. Alloys will be based upon bcc Fe with primary additions of Ga, Al, and Co, and minor additions of Cr, Mn, and B. Structures investigated will be B2 (CsCl), $D0_3$ (BiF_3) and $L1_2$ ($AuCu_3$). The effect of the dependence of the concentration of Ga, Al, and Co on the magnetization, magnetic anisotropy, and magnetostriction will be examined over a broad temperature range from cryogenic temperatures to above room temperature.

3.1.1.1 The effect of the dependence of the concentration of Ga in Fe-Ga alloys on the magnetization, magnetic anisotropy, and magnetostriction will be examined in detail. Emphasis will be on the "double" peak nature of the magnetostriction.

3.1.1.2 Annealing of Fe-Ga alloys under compression and/or magnetic field - Annealing of Galfenol (Fe-Ga) alloys in the range of 19% Ga has shown that an internal anisotropy energy can be developed. This allows for transducer operation of these alloys under tension up to 7 ksi. This important feature will be examined

extensively. Annealing would be accomplished under both compression, tension and magnetic fields. Of great importance is the possibility to achieve near perfect magnetomechanical transduction ($k \approx 1$) under tensile operation when the product of the tensile load and the saturation magnetostriction equals the built-in anisotropy.

3.1.1.3 Dynamic performance of Galfenol alloys under tensile loads - The transduction properties of stress-annealed Galfenol under tension will be examined at low frequencies (10 Hz – 100 Hz) to extend the results obtained with the previous pseudo-static measurements.

3.1.1.3.1 Strain output, power output and frequency dependence will be determined for various Ga compositions and annealing conditions. The issues of eddy currents and magnetic circuits will be investigated.

3.1.1.4 Aging studies of stress-annealed Galfenol alloys - Many of the transduction features of the annealed alloys depend upon their stability. It is important to determine the highest temperature of operation before the magnetostrictive properties degrade.

3.1.1.4.1 Time/temperature studies will be performed for samples prepared under different annealing conditions. In view of these findings, the optimum annealing conditions will be determined.

3.2 Theoretical Investigation of Magnetoelasticity

3.2.1 Investigation into the physical origin of the magnetoelastic fundamentals leading to the large magnetostriction of the Fe based alloys will be made, including analysis of elastic properties data and saturation magnetostrictions.

3.3 Energy Harvesting

3.3.1 Magnetomechanical alloys can be utilized to take unwanted vibration energy and converting into useful electrical energy. It is important to discern and evaluate the feasibility of converting unwanted mechanical energy (or noise) into useful electrical power using Galfenol and Terfenol transduction devices.

3.4 Ultrasensitive Magnetic Field Sensors

3.4.1 Ultrasensitivity depends on a large value of magnetomechanical coupling *k*. Properly field annealed iron-based amorphous ribbons have large values of *k*, but even larger values of *k* are theoretically possible. The mechanisms that limit *k* in current materials, e.g. geometry (demagnetizing fields), imperfections and inhomogenities, will be explored.

4. GFI

4.1 All applicable technical data including drawings, technical manuals, appropriate and relevant supporting documentation, and sources of scientific information shall be made available by 642 or the West Bethesda technical library.

5. GFE

5.1 The contractor shall be required to work at the government facility located in West Bethesda, MD or at the contractor's facility as requested by the government representative in charge of the project.

5.2 The government shall provide workspace and necessary resources to the contractor if available.

5.3 The contractor may be required to provide computer equipment for contractor personnel.

5.4 The contractor may be required to purchase incidental supplies, not to exceed 20% of total contract value.

5.5 The contractor is required to support facilities and equipments with specialized expertise, not to interfere with routine maintenance, but to assure optimum performance for the specific tasking required by this statement of work, as follows:

5.5.1 Calibration, modification, and operation of existing:

5.5.1.1 Magnetic materials characterization systems, including:

5.5.1.1.1. Vibrating sample magnetometer

5.5.1.1.2. High magnetic field electromagnet

5.5.1.1.3. Load frames with magnetoelastic measurement capabilities

5.5.1.2 Network/spectrum analyzers

5.5.1.3 Environmental Chambers

5.5.1.4 Furnaces

5.5.1.5 Power Supplies

6. PERFORMANCE AND DELIVERY

6.1 All technical support shall be completed NLT 18 months from date of award.

6.2 The contractor shall provide copies of technical information and/or electronic copies of all initiatives as requested by the project technical lead. This includes, but is not exclusive to:

6.2.1 Scientific Reports

6.2.2 Facilities and Equipment modification Documentation

6.2.3 Support on Proposals

6.3 The contractor will provide presentations to peer groups and sponsors as required and relevant to tasking specified, and the format specified, including, but not exclusive to:

6.3.1. PowerPoint

6.3.2. MS Office

6.4 The contractor will coordinate efforts and exchange information with other contractors and government professionals as required and relevant to tasking specified.

7. CONFERENCES AND MEETINGS

7.1 The contractor shall be available for frequent (average 3 – 5 times per week) meetings to be held at NSWCCD, West Bethesda, MD or other location as identified by the technical leader.

7.2 The contractor shall possess the requisite clearance to attend meetings at the SECRET level.

8. TRAVEL

8.1 Local and/or long distance travel may be required to meet project objectives. The technical lead will alert the contractor when and where travel is required.

9. SECURITY REQUIREMENTS

9.1. Personnel with classified clearance at the SECRET level are required.

10. TECHNICAL POINT OF CONTACT

10.1 Ms. Marilyn Wun-Fogle, (301) 227-5968, Fax (301) 227-5434, wunfoglem@nswccd.navy.mil.

10.2 Dr. James Restorff, (301) 227-5440, restorffjb@nswccd.navy.mil

11. SERVICES INFORMATION

11.1 The contractor shall not exercise personal judgment on behalf of the Government. The Government shall not assign sub-tasks or prepare work schedules but shall allow the contractor to meet delivery schedules established in the overall task or project. The technical lead shall monitor work via contractor reports as requested.